EFFECTS OF INDUCTANCE ON THE METALLIZATION REMOVAL OF EXPLODING FILMS

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Abstract

During the electrical explosion of a thin metallized film, the metallization layer is heated rapidly up to vaporization where the film bursts and the metal layer is ejected from the substrate. It has been shown that adding inductance in the discharge path changes the characteristics of the explosion; most notably it alters the energy transfer efficiency. This work sets out to explore the metallization removed as a function of inductance, namely how much of the metallized surface is liberated during the explosion of the film. An image processing technique is used to quantify the metallization removal and the results of this effort are discussed herein.

I. INTRODUCTION

Exploding metallized film has similar electrical characteristics to exploding wire and foil, which allow these conductors to work as substitutes in certain applications. The geometry of exploding film is different since it is thin, flat, and easy to shape; whereas wires are cylindrical and foils are physically robust and thicker than film. The film studied is capacitor-grade aluminum metallized polypropylene film (MPPF), with a uniform layer of metallized coating sputtered on the surface.

When a high density current pulse is applied under certain conditions, the conductors explode forming high temperature, arc discharge plasma. This phenomenon is utilized in applications such as nanopowder production [1]-[3], ceramic joining [4], and fast-acting opening switches [5].

Past studies have revealed the effects of the geometry of the film on the electrical explosion [6]. This paper will focus on the effect of inductance on the metallization removal of exploding film. The amount of metal removed is a critical metric in applications such as nanopowder production.

In the following section, the process for analyzing the metal removed as a function of circuit inductance during the electrical explosion is presented. Section III will report and discuss the results. Section IV is the conclusion and the future works.

II. EXPERIMENTAL METHODS

The MPPF used in these experiments has a metallized aluminum layer approximately 225 Å thick that was deposited using a sputtering process. The dimensions of the films tested were kept constant at 10.2 cm by 2.5 cm. The effective electrical length of the film is 7.6 cm due to the two copper electrodes that cover 1.3 cm of the film on both ends.

A circuit was designed and built to discharge the energy of a capacitor to explode the MPPF. The diagram of the circuit is demonstrated in Figure. 1. A high-voltage dc power supply (Slaughter 122/125-2.5) is used to charge a 2 μF capacitor to 2.5 kV. Switch 1 is used here to disconnect the power supply from the discharge circuit once the capacitor reaches 2.5 kV. Once switch 1 is opened, switch 2 can be closed to allow the flow of current from the capacitor, through the MPPF, to ground. A Tektronix P6015 1000x voltage probe is used to capture the voltage across the MPPF during the discharge, and a Pearson 301 10x current probe is used to capture the discharge current.

Several air core inductors were custom made for use in this experiment. Different combinations of these inductors were placed in series with switch 2 and the MPPF to modify the circuit inductance. For each circuit inductance, ten films were exploded.

Metallization removed was calculated using an optical imaging method. The film is flattened to more accurately image film damaged or wrinkled in the explosion. To do so, the film must be heated while being tensioned to retain its original shape. Figure. 2 shows the spring loaded fixture constructed to stretch the MPPF to its original shape while being heated in an oven. The fixture was designed with stops to stretch the MPPF only to its original length.

The next step is to image the flattened film with a high resolution computer scanner (Canon CanoScan LiDE 30) at 1200 dots per linear inch (dpi). A sheet of red poster board is placed on top of the film to provide a contrasting color that will be easy to detect during the image processing. On top of the paper, a piece of Plexiglas (12.7 cm x 7.6 cm x 1.3 cm) is positioned to evenly displace the weight of the scanner lid and reduce wrinkles.

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14. ABSTRACT
During the electrical explosion of a thin metallized film, the metallization layer is heated rapidly up to vaporization where the film bursts and the metal layer is ejected from the substrate. It has been shown that adding inductance in the dis-charge path changes the characteristics of the explosion; most notably it alters the energy transfer efficiency. This work sets out to explore the metallization removed as a function of in-ductance, namely how much of the metallized surface is liber-ated during the explosion of the film. An image processing technique is used to quantify the metallization removal and the results of this effort are discussed herein

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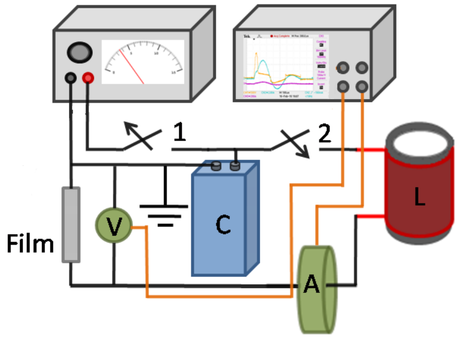

Figure. 1. Exploding film discharge circuit diagram.

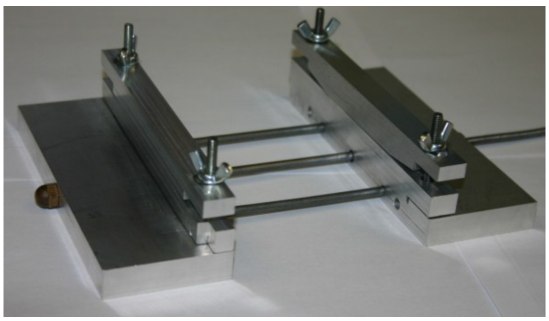

Figure. 2. Fixture constructed to flatten the MPPF to its original size while being heated in an oven.

The scanned image is imported to MATLAB to calculate the metallization still on the MPPF. The luminance of the blue and green components is nearly equal for each pixel and is therefore subtracted from the image to create a grayscale image. In this new image the darker regions represent areas where metallization has occluded the red backing, while the lighter regions correspond to the red of the board showing through the polypropylene backing, representing no metallization. From this image, the number of pixels is plotted against the lightness of the pixels in a histogram. In the histogram there are typically three local maxima, where the first peak represents the metallization and the next two maxima correspond to red background dimmed by the polypropylene film and the red background itself, respectively. A threshold value is chosen from the valley between the first and second maxima to distinguish metallization from the red background. The program then converts the pixels greater than the threshold to white and the pixels less than the threshold to black. The last step of this method is to count the black pixels. The steps of the program written are shown in Figure. 1.

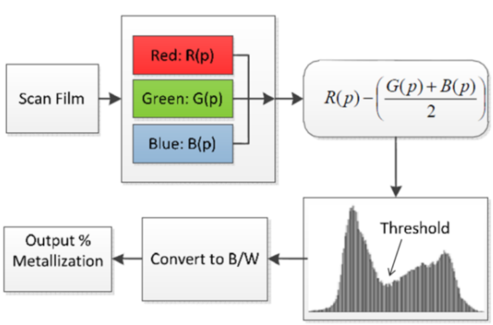

Figure. 1. Flow chart of image processing algorithm.

III. Results

Films were scanned from discharges at several different circuit inductances. The average metal removed was plotted against the circuit inductance shown in Figure. 3. Inductances greater than 0.035 mH show a nearly logarithmic decrease in the amount of metal removed as the circuit inductance increases. For inductances less than 0.035 mH, the metallization removed increases with circuit inductance.

The trend greater than 0.035 mH in the graph can be best explained by the relationship between energy efficiency and circuit inductance. As the circuit inductance increases, the rate at which current passes through the inductor decreases. This decreases the amount of energy in the initial strike, the period during which the metallization is removed [7].

But this relationship does not explain the points less than 0.035 mH on the graph, which indicates another variable affecting the amount of metal removed needs to be taken into account. Further testing will need to occur in an effort to find these other factors.

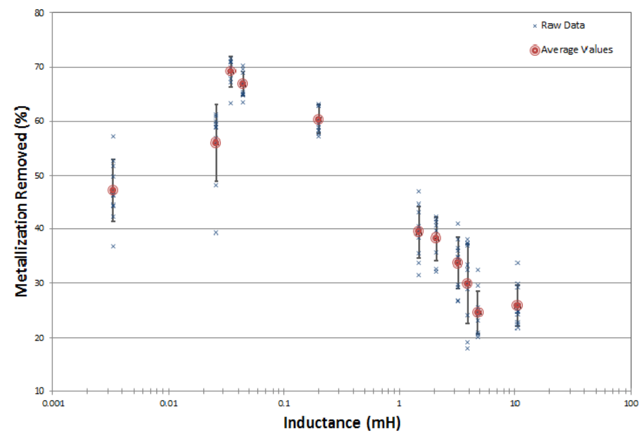

Figure. 3. Average metal removed with standard deviation as a function of circuit inductance.

IV. Conclusion

The effect of inductance on the metallization removal of exploding films has been studied and presented. The results showed that around 0.035 mH the most metallization is removed. The optical imaging methods used to determine the metallization removed proved to be effective and repeatable and will be used in future tests. Further testing will be done on a circuit with lower parasitic inductances in an effort to find the other factors affecting the metallization removed at low inductances.

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